Tandem Canoe 18' - rounded versus squared sections and performance comparison
Revision 1 – comparison also considering a same Cp

Jean-Francois Masset *February 2019* jfcmasset@outlook.fr

Investigation done with « Gene-Hull VE Canoe » application, at same :
Lwl : 5,13 m ; Displacement = 0,200 m3 (Hull with 2 crew as payload) ; **Cp = 0,52** ; GM = 16 cm
and same : Loa (18'), Free boards, Sheer line

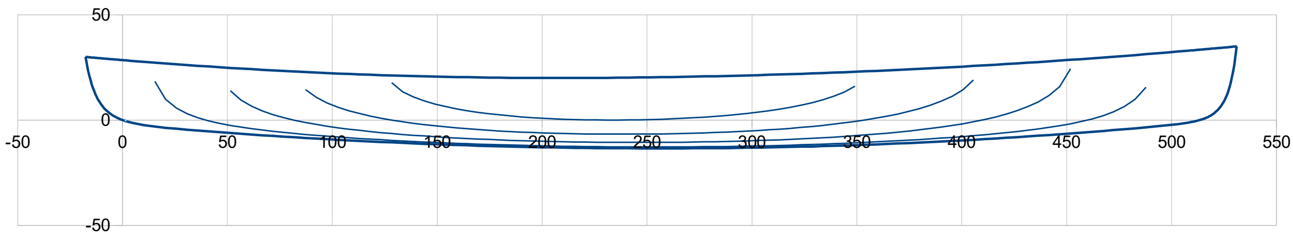
>>> adjusted dimensions for each version concern :

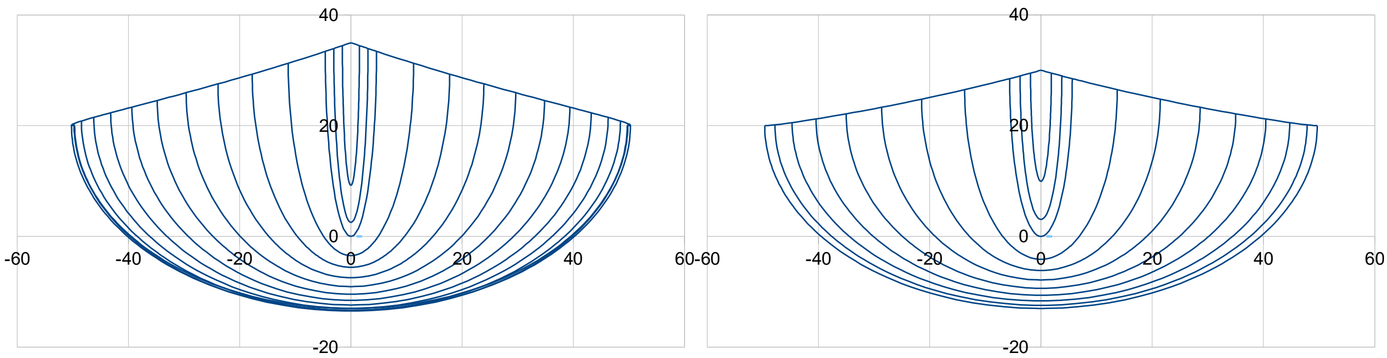
Boa, Bwl, Tc (Hull draft), adimensional parameters defining the hull sections

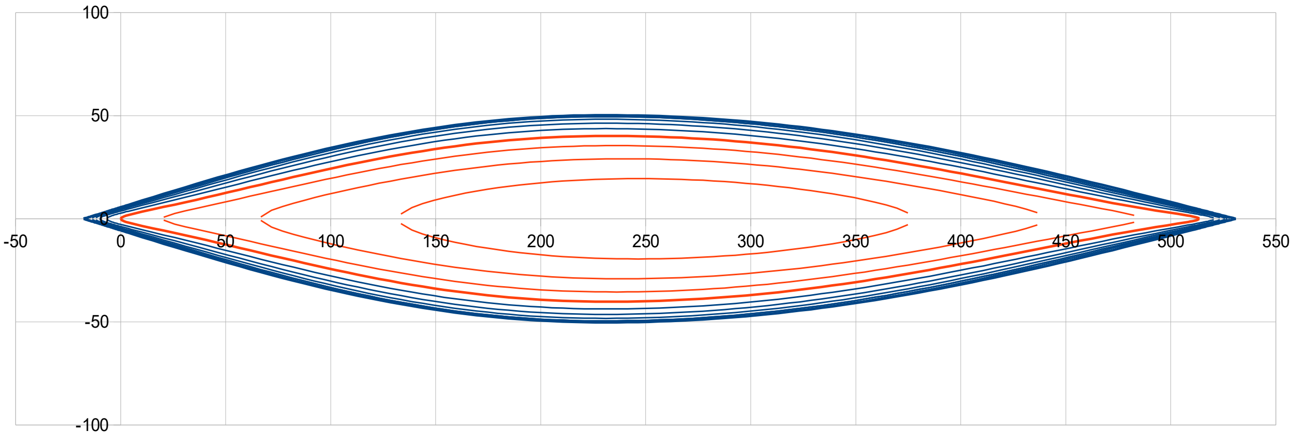
The keel line rocker is also adjusted to maintain a same Cp 0,52

Comment : within the frame of the parametric formulation used for the residuary drag (see in annex) and the values of the other parameters, Cp = 0,52 leads to the minimum drag at the objective Fn 0,325 (0,52 being the lower limit of use of the formulation, may be that lower Cp is even better but no data are available to underpin that).

1. With full rounded sections (elliptical arcs for every sections)







Hydrostatic data :

Hull								
Loa (m)	5,486	Lwl (m)	5,13	> Lwl/D^(1/3)	8,78	Fn at 5 mph	0,315	
>> ft	18,00	>> ft	16,84	DLR	41	M(lbs/2240)/(Lwl(ft)/100)^3		
B (m)	1,005	at X (% Lwl)	45,0					
>> inch	39,57							
Bwl (m)	0,8035	at X (% Lwl)	45,0	> Bwl / B	0,799	Bwl/Loa	0,14646	
				Freeboards (m) >		Aft	Midship	Fore
Tc (m)	0,1347	at X (%Lwl)	50			0,30	0,20	0,35
>> inch	5,30				>> inch	11,81	7,87	13,78
Displacement at H0 (m3)		0,20021	at Xc (m)	2,486	Xc (%Lwl)	48,42	Zc (m)	-0,048
	(kg)	200,21	>> ft	8,16			>> inch	-1,90
	>> lbs	441,4	with water mass / vol. of		1000	kg/m3		
Cp (%)	52,02							
Sf (m2)	2,56	at Xf (m)	2,476	Xf (%Lwl)	48,23	>>> Xc – Xf (%Lwl)		0,19
>> ft2	27,52	>> ft	8,12					
Angle immersed sheer li (°)		21,9	at section C4 (40% Lwl)					
Sw (m2)	2,79	>Sw/D^(2/3)	8,17					
>> ft2	30,08							

Stability :

With this simplified mass spreadsheet (assuming payload Cg at ~ 0,27m), the stability at heel 0,1° is computed :

Simplified Mass spreadsheet	Hull weight unit (kg/m2)	Mass (kg)	Zg (/H0) (m)	Zg (m)
Canoe (kg)	4,18	23,60	0,02	0,021
Load (kg)		176,61	0,27	0,270
M tot (kg)		200,2		
Zg tot (m)				0,241

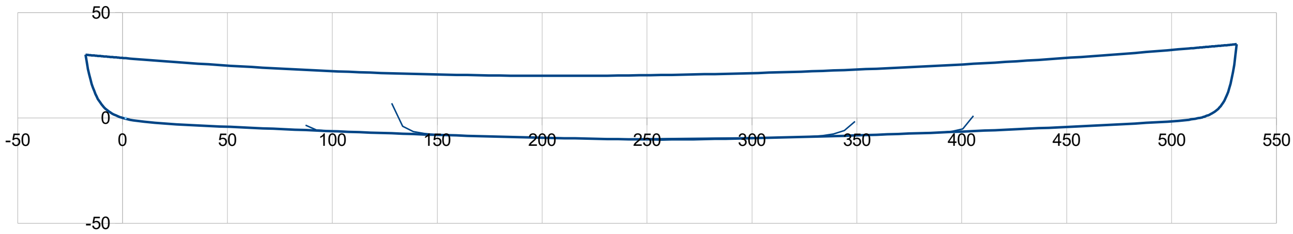
Data to enter		Results					
Heel (°)	0,1	Disp. Heel 0°	0,20021	Disp tot(m3)	0,20021		
Height (cm)	0,0000	> Disp. (m3)	0,20021	>> Lwl (m)	5,133	>> Bwl (m)	0,798
		Xc (m)	2,49	/ Xc Heel 0°	2,49	>> Draft (m)	0,135
		Yc (m)	0,00	/ Yc Heel 0°	0,00	Ym (m)	0,00
		Zc (m)	-0,05	/ Zc Heel 0°	-0,05	>> GZ (m)	0,0003
		>> Sw (m2)	2,79	/ Sw Heel 0°	2,79	GM (cm)	15,8

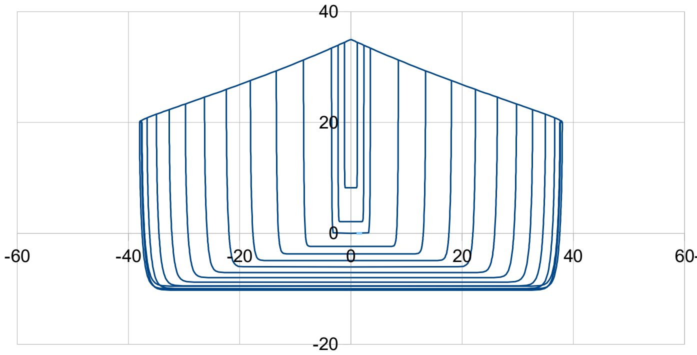
Performance :

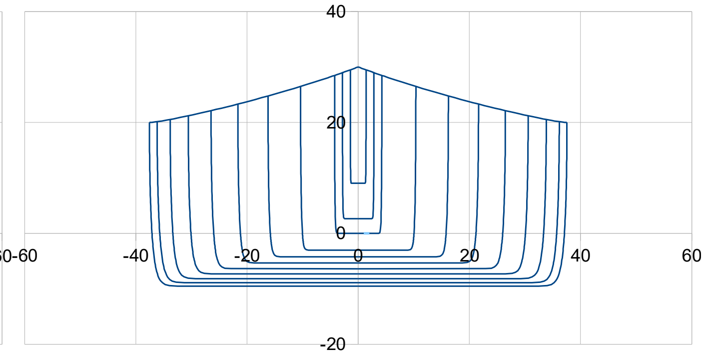
Total drag at Fn 0,325 : 33,08 N

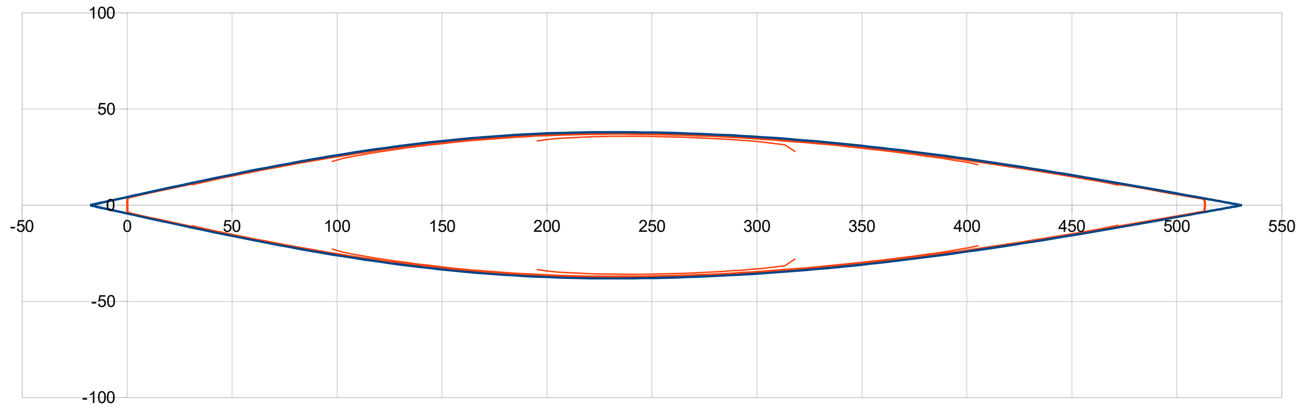
Speed at 80 W propulsion net power, no wind : **Vb = 4,54 Knots** (Fn = 0,329)

2. With full squared sections









Hydrostatic data :

Hull								
Loa (m)	5,486	Lwl (m)	5,13	> Lwl/D^(1/3)	8,78	Fn at 5 mph	0,315	
>> ft	18,00	>> ft	16,84	DLR	41	M(lbs/2240)/(Lwl(ft)/100)^3		
B (m)	0,760	at X (% Lwl)	45,0					
>> inch	29,92							
Bwl (m)	0,7511	at X (% Lwl)	45,0	> Bwl / B	0,988	Bwl/Loa	0,13690	
				Freeboards (m) >		Aft	Midship	Fore
Tc (m)	0,1025	at X (%Lwl)	50			0,30	0,20	0,35
>> inch	4,04				>> inch	11,81	7,87	13,78
Displacement at H0 (m3)	0,20022	at Xc (m)	2,492	Xc (%Lwl)		48,55	Zc (m)	-0,042
(kg)	200,22	>> ft	8,18				>> inch	-1,65
>> lbs	441,4	with water mass / vol. of			1000	kg/m3		
Cp (%)	52,06							
Sf (m2)	2,60	at Xf (m)	2,492	Xf (%Lwl)	48,55	>>> Xc – Xf (%Lwl)		0,00
>> ft2	28,03	>> ft	8,18					
Angle immersed sheer li (°)	28,0	at section C4 (40% Lwl)						
Sw (m2)	3,12	>Sw/D^(2/3)	9,13					
>> ft2	33,62							

Stability :

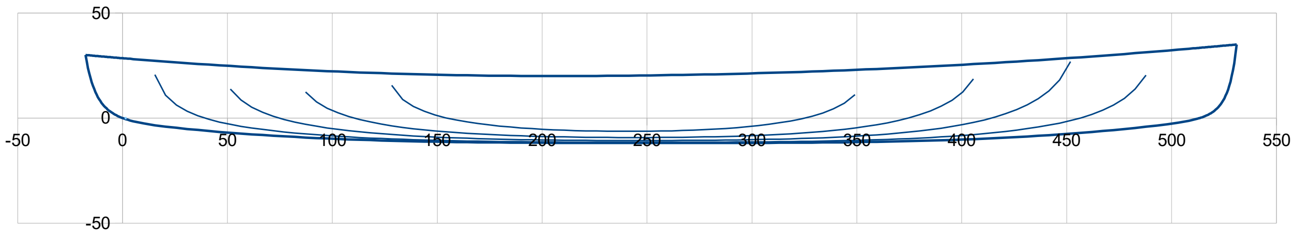
Data to enter		Results					
Heel (°)	**0,1**	Disp. Heel 0°	**0,20022**	**Disp tot(m3)**	**0,20022**		
Height (cm)	**0,0000**	**> Disp. (m3)**	**0,20022**	>> Lwl (m)	5,133	>> Bwl (m)	0,746
		Xc (m)	2,49	/ Xc Heel 0°	2,49	>> Draft (m)	0,103
		Yc (m)	0,00	/ Yc Heel 0°	0,00	Ym (m)	0,00
		Zc (m)	-0,04	/ Zc Heel 0°	-0,04	>> GZ (m)	0,0003
		>> Sw (m2)	3,12	/ Sw Heel 0°	3,12	**GM (cm)**	**15,9**

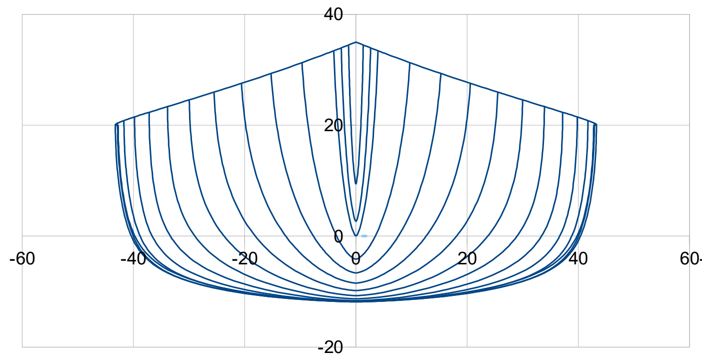
Performance :

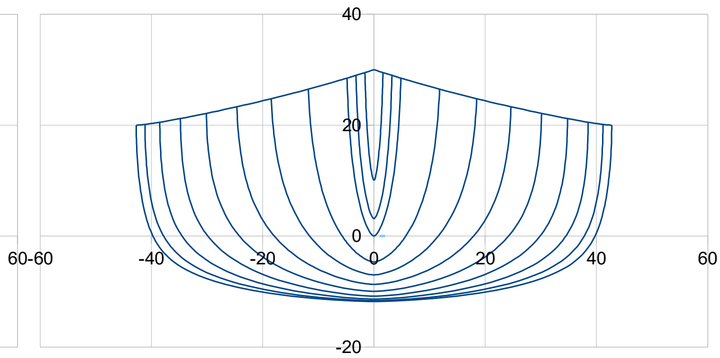
Total drag at Fn 0,325 : 36,64 N

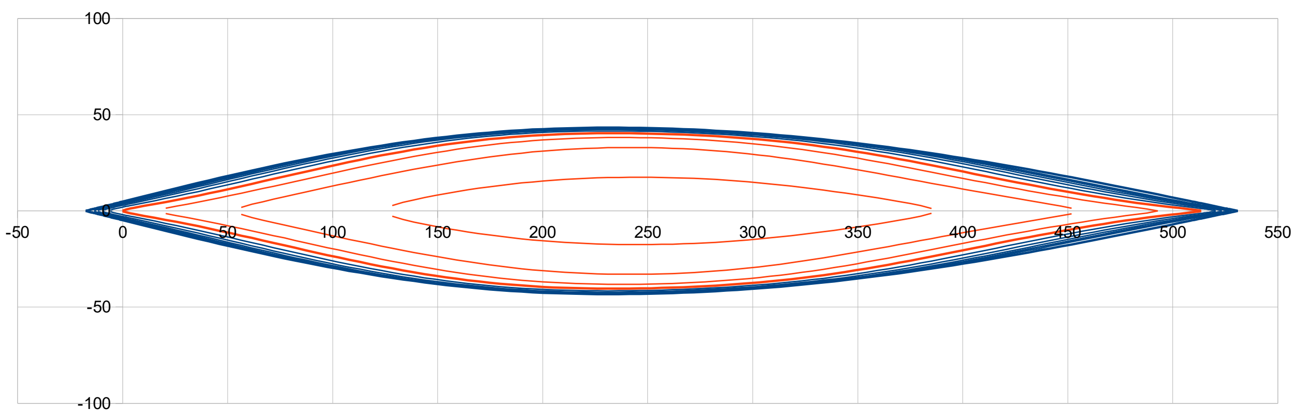
Speed at 80 W propulsion net power, no wind : **Vb = 4,41 Knots** (Fn = 0,32)

3. With V rounded squared sections









Hydrostatic data :

Hull								
Loa (m)	**5,486**	**Lwl (m)**	**5,13**	> Lwl/D^(1/3)	8,78	Fn at 5 mph	0,315	
>> ft	***18,00***	***>> ft***	***16,84***	*DLR*	*41*	*M(lbs/2240)/(Lwl(ft)/100)^3*		
B (m)	**0,865**	**at X (% Lwl)**	**45,0**					
>> inch	***34,06***							
Bwl (m)	**0,8076**	**at X (% Lwl)**	**45,0**	> Bwl / B	0,934	Bwl/Loa	0,14721	
>> inch	***31,80***			**Freeboards (m) >**		**Aft**	**Midship**	**Fore**
Tc (m)	**0,1185**	**at X (%Lwl)**	**50**			**0,30**	**0,20**	**0,35**
>> inch	***4,67***				***>> inch***	***11,81***	***7,87***	***13,78***
Displacement at H0 (m3)	**0,20023**	**at Xc (m)**	**2,469**	**Xc (%Lwl)**	**48,09**		**Zc (m)**	**-0,046**
(kg)	**200,23**	*>> ft*	*8,10*				*>> inch*	*-1,82*
>> lbs	***441,4***	*with water mass / vol. of*	*1000*	*kg/m3*				
Cp (%)	**52,02**							
Sf (m2)	**2,50**	**at Xf (m)**	**2,460**	**Xf (%Lwl)**	**47,92**		>>> Xc – Xf (%Lwl)	0,17
>> ft2	*26,86*	*>> ft*	*8,07*					
Angle immersed sheer Ii (°)	**25,1**	at section C4 (40% Lwl)						
Sw (m2)	**2,78**	>Sw/D^(2/3)	8,12					
>> ft2	*29,91*							

Stability :

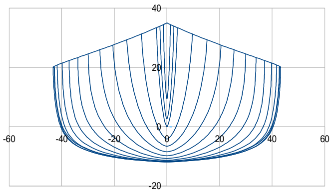
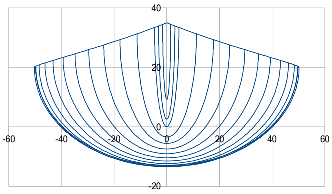
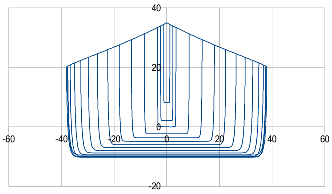
Data to enter		**Results**					
Heel (°)	**0,1**	Disp. Heel 0°	**0,20023**	**Disp tot(m3)**	**0,20023**		
Height (cm)	**0,0000**	**> Disp. (m3)**	**0,20024**	>> Lwl (m)	5,133	>> Bwl (m)	0,803
		Xc (m)	2,47	/ Xc Heel 0°	2,47	>> Draft (m)	0,119
		Yc (m)	0,00	/ Yc Heel 0°	0,00	Ym (m)	0,00
		Zc (m)	-0,05	/ Zc Heel 0°	-0,05	>> GZ (m)	0,0003
		>> Sw (m2)	2,78	/ Sw Heel 0°	2,78	**GM (cm)**	**15,8**

Performance :

Total drag at Fn 0,325 : 33,28 N

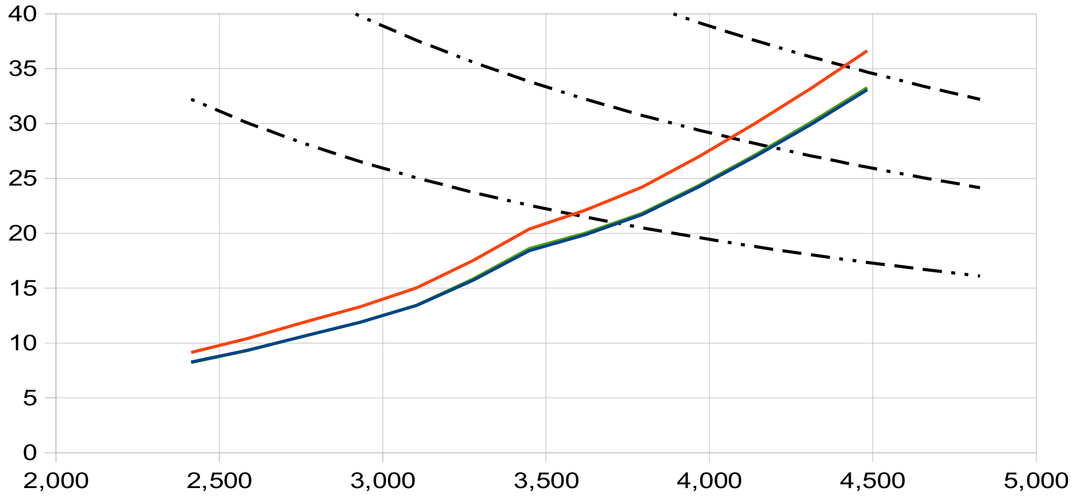
Speed at 80 W propulsion net power, no wind : **Vb = 4,54 Knots** (Fn = 0,329)

4. Summary table

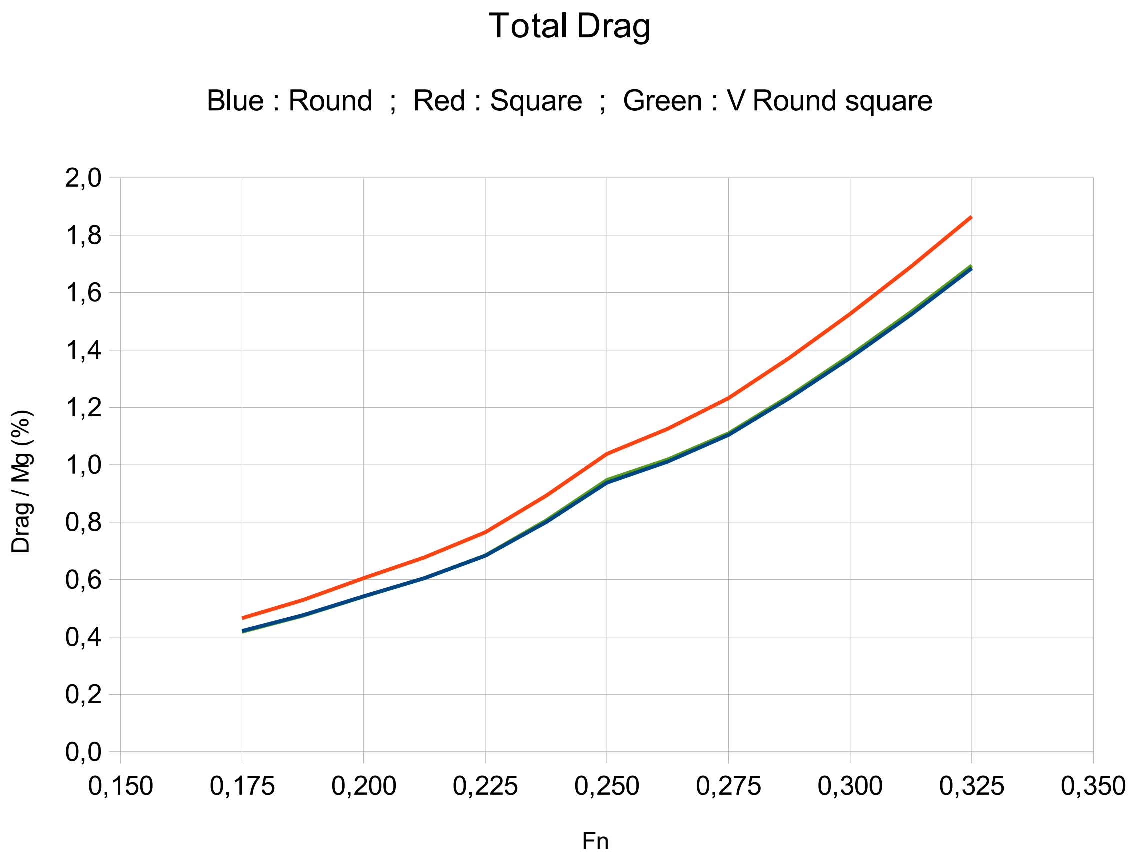
	3. V rounded squared sections	1. Full rounded sections	2. Full squared sections
			
Loa (m)	5,486	5,486	5,486
Lwl (m)	5,13	5,13	5,13
Boa (m)	0,865	1,005	0,760
Bwl (m)	0,808	0,804	0,751
Displacement (m3)	0,200	0,200	0,200
Sw (m2)	2,78	2,79	3,12 (+11,8 %)
Cp	0,52	0,52	0,52
GM0,1° (cm)	15,8	15,8	15,9
Drag (N) at Fn 0,325	**33,28**	**33,08**	**36,64** (+10,8 %)
Speed at 80W net (Knots)	**4,54**	**4,54**	**4,41** (-2,9 %)
Froude	0,329	0,329	0,320

5. Drag comparison

Drag (N) versus Speed (Knots), + power curves at 40, 60 and 80 W (dashed lines)
(Red : Square ; Blue and Green : Rounded and V rounded squared, the 2 curves actually coincide)



Same Drag curves in adimensional units



Annex : Drag components computation

Total drag = Residuary drag + Friction drag + Aero drag

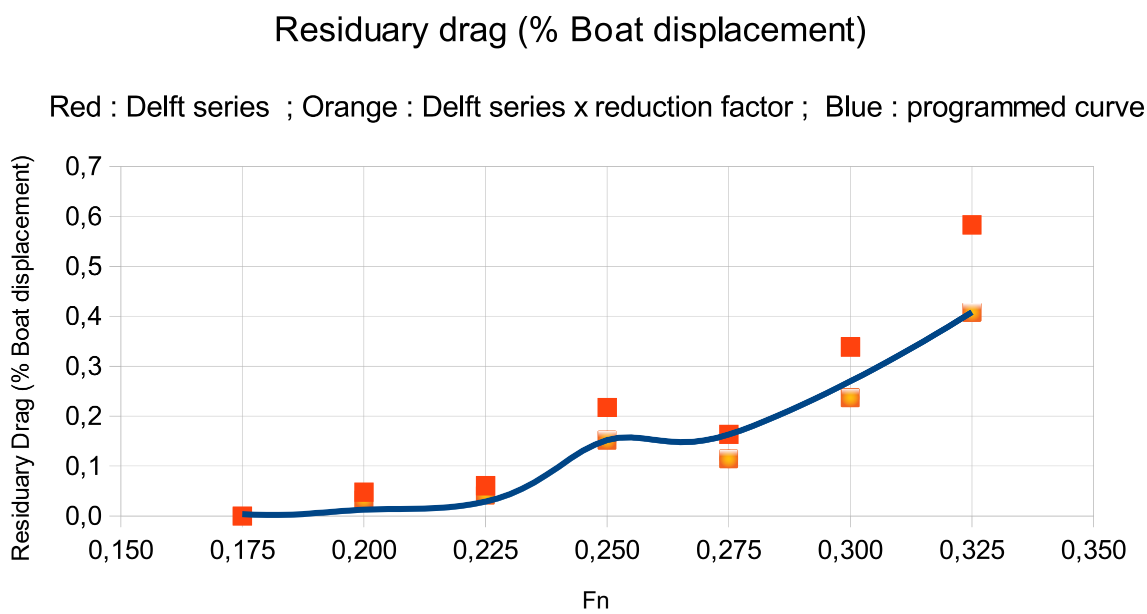
For the Residuary drag adimensional curve :

The residuary drag is estimated using the Delft series and the derived parametric formulation as given in book « Principle of Yachts Design » L. Larsson and R. Eliasson, 2[nd] edition 2000. This adimensional formulation is a drag/displacement ratio in function of Froude, and use 4 parameters (for Froude < 0,45) : Bwl/Tc , Lw / D^(1/3) , Cp , LCB

For the canoe issue, we consider :

- the range of Froude Fn 0,175 to 0,325
- a mitigation factor of 0,7 : to take into account the higher Lwl/Bwl ratio of the canoes (usually > 6) compared to the limit of use of these Delft curves (Lwl/Bwl limited to 5), The user can choose another factor.
- and a smooth formulation.

Example for the V rounded squared hull :



Other drag components are :

- frictional drag, based on the wetted surface of the canoe at their total displacement :
  Friction coefficient : ITTC 57 formula with Re based on 0,7 Lwl

- aerodynamic drag, based on :
  - canoe : surface = Beam oa x Bow height and Cx = 0,5
  - 2 persons in paddling mode : surface = 2 x 0,37 m2 and Cx = 0,5